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ADVANCE RESULTS OF THE FIRST EXPEDITION AFTER A PROGRAM OF COMPLEX ENERGY EXPERIMENTS (KENEX-70)

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16. Abstract

Results of the first expedition of the Kenex program, carried out in the desert regions of Central Asia. The main aim of the expedition was to carry out research into the ground layer and free atmosphere. However, other subjects investigated were the energy effects on the underlying surface and heat flows in the atmosphere. Aircraft and helicopters carried out measurements and readings of spectral and integral radiation flows and temperature, moisture and aerosol profiles. Observations made by a ground party at Repetek were directed at wind speeds, moisture, temperature gradients in the 15-m layer and radiation flows at other levels. Tables show the results obtained at this stage.

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ADVANCE RESULTS OF THE FIRST EXPEDITION AFTER A PROGRAM OF COMPLEX ENERGY EXPERIMENTS (KENEX-70)

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Earlier [1] the content and aims were given of the complex /2* energy experiment (Kenex), carried out within the framework of the program into research of global atmospheric processes. One of the main tasks of Kenex -- is research into the radiation factors of general circulation of atmosphere -- discussed in some detail in works [2, 3].

In 1970, The Main Geophysical Observatory im. A. I. Voyeykov and the Central Aerological Observatory, in conjunction with the Leningrad State University, the Central Asian Regional Scientific-Research Hydrometeorological Institute, the Desert Institute of the Academy of Science of the Turkmen Soviet Socialist Republic, the State Optical Institute im. S. I. Vavilov and the Agricultural Physical Institute im. A. F. Ioffe, carried out the first expedition in the Kenex program in the deserts of Central Asia.

The selection for the place of the expedition was determined by the desire to work, during the first stage, in the simplest conditions where there was a cloudless sky and a uniform underlying surface.

During the expedition complex ground, aerological and airborne research was done, the basic aim of which was to work out methodically questions linked with carrying out a wide program of observations in the surface layer and free atmosphere. However,

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* Numbers in the margin indicate pagination in the foreign text.

apart from these methodical workings, a whole range of research was carried out on individual Kenex problems, the advanced results of which are discussed later; these are problems of power interaction with the underlying surface and also determining heat flows in the atmosphere.

Approximately 120 scientific workers, engineers and technicians, apart from the basic personnel of ground stations and crews servicing the aircraft (two IL-18 aircraft-laboratories) and helicopter took part in carrying out the work in all spheres of ground observations, aerological, actinometric, airborne and helicopter probings.

Apart from the authors of the present article, separate parts of the work during the expedition were supervised by: V. A. Ayzenshtat, I. Ya. Badanov, V. S. Grishechkin, L. N. Guseva, V. I. Dmokhovskiy, B. A. Deryugin, V. F. Zhvalev, V. A. Ivanov, N. A. Lazareva, N. S. Orlovskiy, L. N. Prokof'eva, M. A. Prokof'ev, Ye. I. Sofiev, and Z. M. Utina.

The Ground Expedition

The ground expedition was based in the southeastern Karakums (the area of the Repetek desert scientific station). Aerological and actinometric radiosonde observations of the atmosphere (2-3 times at night) were carried out at the Chardzhou aerological /3
station, where, together with standard sounding, sounding with radiosondes of increased accuracy was carried out. Helicopter sounding in the surface layer of the atmosphere in the Repetek station area was also done from a MI-1 helicopter. Measurement of spectral and integral radiation flows of meteorological parameters and aerosol characteristics in the free atmosphere were done by two IL-18 aircraft-laboratories, belonging to the Main Geophysical Observatory and the Central Aerological Observatory, in two regions:

close to the Repetek station and in the central, most uniform part of the Karakum desert, to the west of the settlement of Dargan-Ata. In Fig. 1 are shown the areas where work was done and an approximate flight diagram. When sounding was done in each area of the Dargan-Ata region, aircraft routes were oriented in relation to the Sun shown in the diagram.

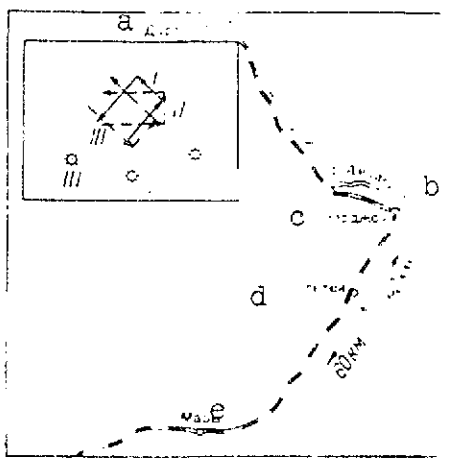

Fig. 1. Flight diagram.

Key: a. Dargan-Ata; b. Amudarja; c. Chardzhou; d. Repetek; e. Mary

During the expedition's work period (from 4 to 29 October) weather in the Repetek-Chardzhou-Askhabad region, in general, was changeable. Settled, clear weather, caused by an area of high pressure over areas of Central Asia, was observed only on some days (4-8, 11-14 and 20-25 October). On the remaining days there were fronts, which were accompanied by upper and medium cloud levels, and on some days by cumulo-nimbus clouds with short showery periods. The air temperature during the day when there was clear weather reached 24-26°C, and at night fluctuated from 0 to 10°C.

The underlying surface in the area of the Repetek station, where ground measurements and aircraft flights were carried out, is a sand hill desert ridge with vegetation covering up to 40% of its surface. The predominant height of the sand hills is 1-3 m, the height of the ridges reaches 20-25 m, and the upper part of the sand hills, as a rule, does not have vegetation; the sand hills, for the most part, point in a north-south direction.

The area, above which flights were made in the Dargan-Ata region, is also composed of small sand hills with an evenly

distributed vegetation, covering up to 5-10% of the surface. The sand-hills point in a north-south direction. To the east of the center of the area, the amount of vegetation falls somewhat and loose sand is met more often. Separate patches of sand of a reddish color without vegetation and salt marshes are found along the eastern edge of the area. Along the southwestern edge of the area there are broad patches of desert soils and salt marshes. Nonuniform areas of the surface are only met along the borders of the area which was chosen and are less than 20%. /4

Observations at Repetek

At the Repetek station, where the ground expedition was based, observations were carried out on:

1) wind direction and temperature and moisture gradients and wind speed in the lower 15-m layer;

2) components of the radiation balance and radiation temperature of the underlying surface;

3) temperatures at various depths and heat-physical characteristics of the soil;

4) radiation flows of heat in the ground layer;

5) turbulent flows of heat (the B.A. Ayzenshtat heat exchange measuring apparatus);

6) spectral transparency of the atmosphere;

7) the concentration of aerosol particles at levels of 2, 5 and 10 m;

8) pilot-balloon observations in the lower 3-km layer;

9) observation of compensated spheres in order to evaluate the dissipation of energy of turbulence when pilot balloons are dispersed;

10) helicopter sounding, during short simultaneous measurement of temperature, moisture, pressure and temperature pulsations, measured the vertical profiles of radiation flows in the boundary layer. Horizontal flight also took place to research into the radiation characteristics of basic desert landscapes.

In order to evaluate horizontal variability of meteorological elements and radiation characteristics, data on net radiosonde observations were taken at Chardzhou, Tashauz, Ashkhabad and Takhta-Bazar stations, as was data on actinometric observations on the net of these stations. Observation was done only at the Akmola station on the special program.

Observations were done in series, lasting several hours each and including a whole range of measurement in each series. The most complete measurements carried out were the actinometric ones. Included in the program of work was the acquisition of radiation characteristics of the underlying surface and measurement of radiation flows (both longwave and shortwave) from the level of the earth's surface to a height of approximately 9 km by using various pieces of equipment.

The choice of times of observations of the land group was determined by the necessity to provide synchronized observation at times when flows of radiant energy change little with time (this condition corresponds to periods 11-14 and 1-4 hours local time) and the necessity to obtain information on the border layer at a time when the condition of the border layer is almost stationary. /5

Analysis of observations showed that these conditions corresponded to the periods 15-17 and 5-7 hours local time.

A daily series of observations was done to determine the characteristics of the daily behavior of components of heat balance and the distribution of meteorological elements. The amount of observations done by the ground group was 115 hour series. Three daily series were carried out during the expedition, when flights by IL-18 aircraft were done over the area and in the region of the Repetek station.

At the ground measurement point, all the instruments were set up on an artificially leveled space measuring 100 × 100 m. To investigate the effect of irregularities of the underlying surface on temperature-wind in the ground layer, in addition to observations done in the main space, observations were also carried out on a ridge and on the windward and leeward slopes of an isolated, well-defined sand hill. Here, observations of the wind speed were carried out to a height of z = 16 m, and an air temperature -- in the layer of 2 m.

Results of Measurement of the Albedo and Temperature

Analysis of data of measurements shows that the reflecting power surrounding the area of the ground expeditions is quite uniform. In Table 1 are given the albedo values of various types of underlying surface, obtained by data measured with an albedometer placed in a helicopter.

As follows from Table 1, the albedo of the basic landscape of the southeast Karakum changes very little.

The temperature in the area of work of the ground expedition was characterized by the considerable, daily ranges, brought about

by the large amounts of shortwave radiation in the daytime and radiation cooling of the underlying surface and the lower air level at nighttime. The amount of radiation balance on cloudless days, in the daytime, was 0.40-0.50 cal/cm^2 min, at night -- 0.06-0.08 cal/cm^2 min.

TABLE 1

Underlying surface	Albedo, %
Valley-shaped depressions with thickets of haloxylon covering 40-70% of the area	20-22
Large sand hills with sparse vegetation	25-26
Small sand hills with haloxylon (the predominant landscape of the eastern Karakums)	24-25

Considerable radiation cooling is caused by the calm weather conditions at nighttime. In daytime, the wind speed at a height /6 of approximately 10 m is 5-6 m/sec, and only on particular days attained 7-7.5 m/sec, which caused a considerable shifting of sand.

The maximum air temperature at a level of z = 2 m for the period of observation was 30°C, the minimum -- approximately 0°C. Night frosts of up to -3°C were noticed in the soil. The daily range of temperature of the underlying surface reached 40°C.

High values for surface temperature at daytime are caused by significant gradients of upward flow of longwave radiation. The vertical profiles of the upward flow $E_L^{\uparrow}$ in the daytime for three moments of time are shown in Fig. 2. From this data, it follows that in the daytime there is a radiation heating in the lower layer of the atmosphere, which appears stronger in the 100-m layer (1.5-2°C/hour).

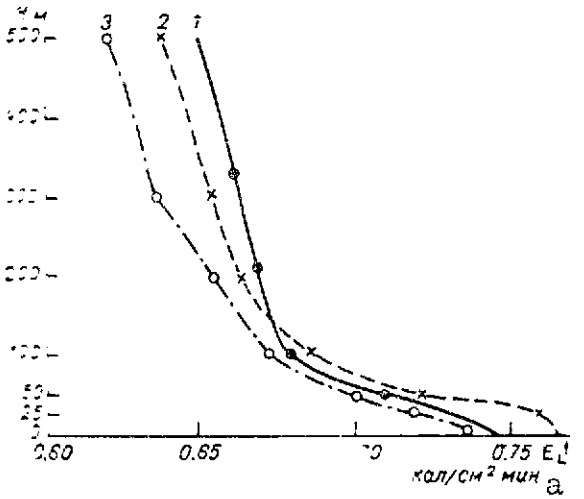

Fig. 2. Measurement of the vertical profile of the upward flow of longwave radiation $E_L^{\uparrow}$ at daytime: 1) 12 hours 00 min; 2) 13 hours 30 min; 3) 15 hours 00 min.

Key: a. cal/cm^2 min

The Program and Results of Observations at Chardzhou

Ground and aerological observations were also carried out by the Central Aerological Observatory Group in the town of Chardzhou and included actinometric radiosonde observations, temperature sounding for determining the structure and dynamics of the temperature field and also spectral measurement for determining the direct and diffused solar radiation in the ultraviolet range of the spectrum for determining the overall content and vertical profile of ozone.

In a period from 4 to 26 October, 12 series of actinometric radiosondes were launched, of these, three series of two launches each and nine series of three launches each were done at nighttime.

The overall number of launches was 34 with an average sounding height of 23.6 km.

Preliminary analysis of results of actinometric scunding makes it possible to draw the following conclusions:

1) on cloudless nights in a time of 6-8 hours, the transforma- /7
tion of upward and downward flows of longwave radiation was clearly observed only in the lower troposphere, at heights of up to 3-5 km;

2) according to data from the actinometric radiosondes, in a cloudless atmosphere, there was no occurrence of radiation heating. Radiation cooling was observed: from the Earth's surface to a level of 600 mbar 0.02-0.05°C/hour; in the medium troposphere (600-450 mbar) 0.06-0.07°C/hour; in the area of the tropopause, the speed of radiation cooling was reduced to 0.005-0.01°C/hour, and in the stratosphere, it was 0.02-0.04°C/hour.

Experimental research into the structure and dynamics of the temperature field was carried out by a RKZ-ZA laboratory variation of the radiosonde with an increased accuracy. Launches of the radiosondes were done in two daily series with a time interval of 2-3 hours. Results of measurement make it possible to trace the daily variation of temperature, the evolution of surface inversions of radiation cooling, frontal sections, the arctic and tropical tropopause and also disturbances of the temperature field in the stratosphere.

Data on temperature showed that there is a fluctuation of temperature of a periodic nature in the 30-km layer of the atmosphere. The difference between the daytime maximum and nighttime minimum can reach 1-3°C. In the troposphere there is a tendency for a decrease of range of these fluctuations with the increase of height, and in the stratosphere -- an increase of range.

According to preliminary results of process of data of measurement on the general content of ozone, significant changes of it were observed (from 0.258 to 0.322 cm) depending on meteorological conditions. Vertical profiles of ozone concentration, determined by the reversal effect, are characterized by low centers of gravity and the absence of secondary maxima. Carrying out parallel measurement of horizontal and vertical distribution of ozone with equipment fitted into an IL-18 aircraft (Central Aerological Observatory), showed the considerable space-time variability of content of atmospheric ozone.

Aircraft Observations

The aircraft research program included a wide range of measurement of spectral and integral radiation flows in the atmosphere and was accompanied by auxiliary, meteorological measurements of profiles of temperature, moisture and aerosol. Photographic and infrared images of the underlying surface were obtained to evaluate the optical and radiation irregularity of sections of the underlying surface, above which vertical sounding was carried out.

During the expedition period, 14 flights on an aircraft from the Central Aerological Observatory and 18 flights in an aircraft of the Main Geophysical Observatory were carried out; nine flights were carried out simultaneously by two aircraft. Flights were made by day and night. The duration of one flight, on an average, was 3-3.5 hours, the middle of the flight coinciding timewise with true midday (when the Sun is at its highest). Measurements were made at heights 0.3, 1.3, 2.8, 5.6, and 8.4 km, corresponding to the standard isobaric surfaces. Passes on varicus azimuths in /8
relation to the Sun were carried out on each area, in order to obtain corresponding information by all instruments.

Solarimeters and pyrgeometers were installed in the aircraft and with these the upward and downward flows of integral shortwave and longwave radiation weremeasured. The results of measurement on each area were averaged out. Process of measurement, carried out by aircraft from the Central Aerological Observatory and the Main Geophysical Observatory, was done by the same method.

This made it possible to obtain for the first time simultaneous data of measurement of radiation flows at various levels, which makes it possible to solve completely the problem of radiant influx of heat to individual atmospheric layers.

Analysis of Results of Aircraft Measurement

In order to interpret the results obtained, data on the measurement of atmospheric aerosol was used; this was done in an aircraft from the Main Geophysical Observatory by using a filter trap. During processing, the concentration count of aerosol and size distribution of particles with a radius of 0.3 to 3 μm was determined.

Preliminary comparison of results of processing of measurement of radiation flows shows that there is a satisfactory correlation between data from the Main Geophysical Observatory and the Central Aerological Observatory. As an example, in Fig. 3 are shown the vertical profiles of the shortwave B_S and the longwave B_L balance, and also data on the distribution of high concentration aerosol N for 25 October. From this figure, one can see clearly the effect of aerosol on the absorption of radiation by the atmosphere.

Analysis of measurement material obtained made it possible to form some conclusions on the role of radiation factors in the formation of a temperature field in the troposphere. In a cloudless atmosphere the speed of radiation heating of the lower troposphere is in the order of 0.05-0.1°C/hour. In the middle troposphere (to a height of 7 km) this value is approximately equal to 0.05°C/hour. The rate of cooling of these layers by longwave exchange, when there are no clouds, is, for the lower troposphere, 0.03-0.05°C/hour, for the middle -- approximately 0.07°C/hour.

These conclusions, obtained from the results of aircraft measurement, agree satisfactorily with actinometric radiosonde observations shown earlier.

To obtain information on spectral flows, the angular distribution of upward and downward radiation and the spectral composition

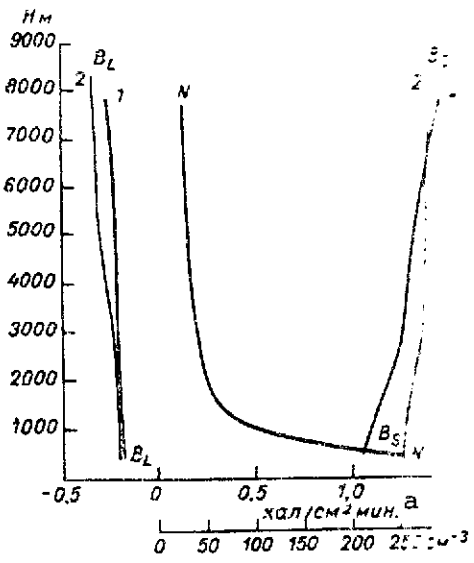

Fig. 3. Vertical profiles of shortwave B_S and longwave B_L balance and the distribution of concentration of aerosol N:
1) data from the Main Geophysical Observatory;
2) data from the Central Aerological Observatory.

Key: a. cal/cm^2 min

of direct solar radiation, five types of spectrometers, the basic technical characteristics of which are shown in Table 2, were fitted into an IL-18 aircraft (Main Geophysical Observatory).

When measurements were made with K-2 instruments, the distribution of energy in downward and upward shortwave flows of radiation at various levels in the free atmosphere was determined. Processing of the data made it possible to find the spectral distribution of balance (difference in upward and downward flows) of shortwave radiation at various levels in the /9 atmosphere. As an example, in Fig. 4 is shown the dependence of

TABLE 2

Type of measurement	Type of instrument	Spectral interval, m	Spectral resolution, m	Measurement time of one spectrum, sec
Downward and upward flows	K-2	0.35—1.1	0.002	10
Angular distribution of intensity and brightness coefficient	SPI-2M	0.4—2.5	0.003—0.05	6
Angular distribution of intensity and brightness coefficient	SP-102	2.0—5.6	0.07	120
Angular distribution of intensity of radiation	SP-123	5.0—13.0	0.2	120
Direct solar radiation	IKSS-1	0.7—4.1	0.05—0.1	40

spectral balance B_λ on the wavelength for two levels in the atmosphere (H_2 = 8400 m, H_1 = 300 m). Measurement of the zenith angle of the Sun for the time when the spectrum was measured was 2°. Since one of the main problems, linked with the effect of the radiant influx of heat on thermal conditions and the dynamics of the atmosphere, is the study of the role of aerosol as a absorbent component of the atmosphere curves in Fig. 4 are plotted on points, which correspond to wavelengths, outside of absorption bands.

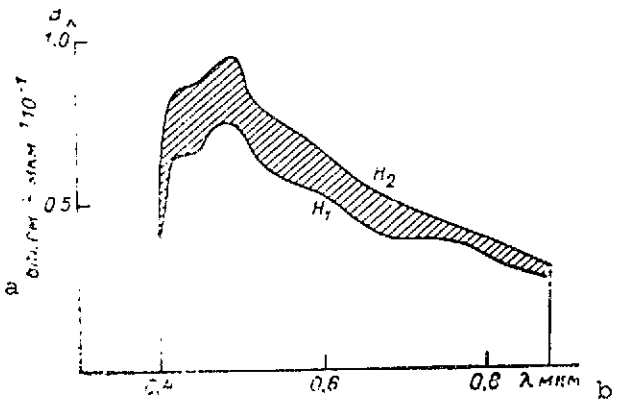

Fig. 4. The spectral balance B_λ of shortwave radiation for two levels.

Key: a. $W \cdot cm^2\ \mu m^{-1}\ 10^{-1}$
b. μm

It is obvious that in this case, the hatched area characterizes the spectral radiant influx $b_\lambda = \Delta B_\lambda / \Delta z$ for a layer of the atmosphere from 300 to 8400 m, caused by the absorption of shortwave radiation by an aerosol. /10

It must be mentioned that the experiment which was examined made it possible, for the first time, to observe the absorption of shortwave radiation by aerosol in relation to the wavelength and evaluate the corresponding influxes of heat by direct measurements.

As can be seen from Fig. 4, the value of radiant influx of heat as a result of absorption by aerosol slightly decreases with the increase of wavelengths, which, obviously, can be explained by the selectivity of a complex refractive index of aerosol. An evaluation of the value of radiant influx of heat b_λ is about 5% in relation to the flow of solar radiation, arriving from above at a height H - 8400 m.

Measurement by SPI-2M, SP-102 and SP-123 instruments makes it possible to obtain the angular distribution of intensity of upward and downward radiation in absolute units at different levels in the atmosphere. Here, calibration of the SPI-2M instrument is done in laboratory conditions by recording the spectrum of a SI-8-200 band lamp with the known distribution of energy, and also by measuring the brightness of a matt opal plate, illuminated by the Sun when flying at great heights. Calibration of the SP-102 and SP-123 instruments was done during measurement by detecting the spectrums of radiation of black bodies with a fixed temperature. In Fig. 5 is shown an example of energy distribution in an upward radiation spectrum when measuring at the nadir from various heights, obtained by using the SPI-2M and SP-102 instruments.

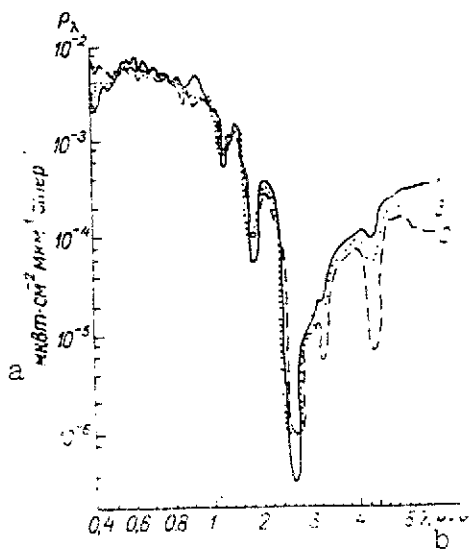

Fig. 5. Spectral brightness P_λ of the ground surface-atmosphere system from various heights (measurement at the nadir): 1) 300 m; 2) 8400 m; 3) 2850 m.

Key: a. $\mu W \cdot cm^{-2}\ \mu m^{-1}$ steradian
b. μm

During the expedition, the SPI-2M instrument was used for obtaining more than 600 spectrums, characterizing the spectral distribution of energy brightness of the desert, sky and clouds at various angles. Analysis of the angular relation of brightness of the desert showed that there was a considerable variation in the blue range of the spectrum and a smaller one in the infrared range, which is determined, basically, by the effect of scattering indicatrix. The increase of brightness from the nadir to the horizon was also considerably greater in the blue range of the spectrum, but was traced on all wavelengths. /11

Infrared photography showed that there was considerable radiation nonuniformity of the surface, caused by nonuniform heating by the Sun of differently oriented sections of the sand hills. This nonuniformity can appear when measurement is done with narrow-angle instruments from small heights and must be taken into account.

In conclusion, let us say that, at the present time, the collective of members of the expedition of the Kenex program is concluding the first stage of detailed processing of material and preparing on the subject a selection of scientific publications.

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